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Asymmetric Exchange Rate Pass-Through in Southeast Asian Rice Trade

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Abstract

Asian countries consume approximately 90% of the world's rice supply. Between 2007 and 2014, Thailand, Vietnam, and India accounted for 60% of the world's exports of rice. This paper estimates the impact of exchange rate fluctuations on bilateral trade flows in Southeast Asia. Because most Southeast Asian countries have state trading enterprises or agencies controlling rice trade, this analysis will provide insight as to whether these agencies respond to exchange rate fluctuations in a manner consistent with economic theory. Behavior inconsistent with economic theory could provide evidence of stabilizing domestic prices, market power, or export expansion policies. The analysis focuses on the main Asian importers, by volume, of rice (Malaysia, Indonesia, and China) from one of the largest, by volume, Asian rice exporters (Thailand). Another novel aspect of this analysis is the model employed. A nonlinear autoregressive distributed lag econometric model is utilized. The dependent variable is the bilateral importing LCU real value. The independent variables include lagged dependent variables, exchange rates, and real GDP per capita of the importing country. Results show countries' state trading enterprises are not optimizing import decisions as purchasing power fluctuates, which is the opposite of exchange rate theory.

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Dedication

This thesis is dedicated to my original professor in agricultural economics at Southern Arkansas University – Dr. Pierre Boumtje. Dr. Boumtje sparked my interest in agricultural economics. My interest was catapulted as I took classes building on the fundamentals of agricultural economics in policy and international trade. He was one of the first people who encouraged me to pursue a master's and told me he believed I could do it. I am grateful for his guidance in the application and selection process. To this day, he continues to be a supporter, mentor, and friend. Dr. Boumtje – you believed I could do this and now I believe it too. Thank you.

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1. Introduction

Rice is an important crop in the world. Large rice consuming countries often import rice to fill their domestic demand, but have the goal of being self-sufficient. Rice is a staple crop for almost half of the world's population (Hoang & Meyers, 2015) and is particularly important for Asian countries. Ninety percent of rice is grown and consumed in Asia (Kim & Andres Ramirez, 2014; Ricepedia, 2020). For instance, almost one third of daily calories come from rice in Southeast Asia (Glamalva & Weaver, 2015). The importance of rice continues to grow as shown by the United States Department of Agriculture (USDA) Economic Research Service (ERS) 10-year projections, which estimates world rice consumption will increase 5.5% by 2028 (USDA, 2019).

Shifting to the international market, rice is thinly traded because of high domestic consumption in the majority of rice producing countries. In 2012, only about 6% of total rice production was traded on the international market (Chen & Saghaian, 2016). From 2007 through 2014, 8% of rice production was traded, compared to 37% for soybeans and 21% for wheat (Glamalva & Weaver, 2015). Consequently, international rice prices fluctuate greatly with supply shocks due to biotic or abiotic stresses or trade restrictions by rice exporting countries. Annual imports of milled rice to Southeast Asia averaged 4,823,000 metric tons between 2002 and 2018, with 3,090,000 metric tons at the lowest and 6,518,000 metric tons at the highest (PSD, 2020). With rice traded on the international market increasing, understanding how importing countries respond to exchange rate fluctuations is increasingly important. Several rice trading countries, such as the ones discussed in this paper, are concerned that their rice trading partners are strongly committed to protecting domestic prices – high for producers and low for consumers. With low trade volumes, these actions can highly distort international rice prices.

Working to ensure a high price for farmers and a low price for consumers means governments must find ways to make up the cost difference. Government intervention in domestic rice markets may destabilize the international rice market because of the heavy costs involved, misallocation of scarce resources, market distortions, attempts to re-stabilize prices, and increases in volatility (John, 2013).

Switching to the domestic market, price stability is a major focus of Asian governments because of the influence the price of rice has on self-sufficiency, food security, and political stability. To cushion against international price volatility, rice importing countries, such as Malaysia, Indonesia, and the Philippines, are diligently working towards self-sufficiency (Clarete, Lourdes, & Esteban, 2013). Consumer preferences are strong in Southeast Asia as rice is differentiated by processing, length, type, and variety (Glamalva & Weaver, 2015). Even Yumkella, Unnevehr, and Garcia noted importers of rice are loyal to variety, origin, and brand in 1994. These preferences cause inelastic rice markets. Rice is a staple food and therefore, consumers will continue to purchase even as the price rises. Consequently, when rice prices are high, consumption of other foods high in protein, vitamins, and minerals are often reduced due to decreased purchasing power. High rice price can cause long-term health problems such as stunting and anemia. Therefore, governments in Southeast Asia have concluded that price stability acts as an important safety net for society (Dawe, 2002). As a result, the rice industry in many Southeast Asian countries has been highly regulated to achieve domestic price stability and self-sufficiency (Omar, Shaharudin, & Tumin, 2019).

Free trade would be the preferred option, because free trade encourages competition and discourages rent seeking behavior, but Asian countries typically limit free trade with regards to rice. Rent seeking behavior is more likely when there are fewer suppliers or exporters, as seen with the international rice market. Rice trading countries see the benefits of price stabilization where producers receive a higher price and consumers pay a lower price (Dawe, 2000).

With this shared concern in Southeast Asia of unfair rice prices, many rice importing countries have opted to create a state trading enterprise (STE) or agency. Addressing unfair prices could mean increasing price for producers or lowering price for consumers, or both in the case of price stabilization. In Southeast Asian rice trade, STEs control a majority of the trade since the governments bestow on STEs complete control of imports. The goals of an STE differ from profit-maximizing trade agencies, which may prohibit rice markets to respond to fluctuations in exchange rates, along with other changes in market conditions. Some of these alternative goals include food security, farmer support, political stability, self-sufficiency, or maintaining culture norms. Reed (2001) shows prices for tradable goods should be equal across countries if exchange rates are not manipulated. Understanding the motives and behaviors of STEs start with studying how STEs respond to exchange rate volatility through exchange rate pass-through. From the importer's perspective, if their currency appreciates then more of the exporting country's currency can be purchased. This increases the purchasing power of the importer and imports should rise. By contrast, depreciation of the exchange rate means importers can purchase less of the exporting country's currency, implying imports are more expensive. The purchasing power of the importer falls and imports should decrease. Therefore, as an importing country's currency appreciates (or depreciates), quantity imported should rise (or fall).

The literature analyzing exchange rate pass-through in food and agriculture is limited, particularly for rice trade in Asia. There is extended literature on exchange rate pass-through for non-agricultural commodities such as oil. For example, see Atil, Lahiani, & Nguyen (2014); Bachmeier & Griffin (2003); Bagnai & Opsina (2015); Bagnai & Opsina (2016); Bagnai &

Opsina (2018); Jammazi, Lahiani, & Nguyen (2015); and Kilian (2008). Within agriculture, Pompelli and Pick (1990) analyze pass-through of exchange rates and per unit tariffs in non-competitive tobacco markets, finding prices do not fully pass-through. Miljkovic, Brester, and Marsh (2003) find incomplete exchange rate pass-through in US meat exports. However, their results do not show the cause of the price distortion. Miljkovic and Zhuang (2011) use meat-weighted exchange rates to estimate pass-through in US meat exports to Japan. Their results show poultry and beef have partial pass-through whereas pork has zero pass-through in exchange rates. To the best of our knowledge, Yumkella et al. (1994) is the most recent study analyzing exchange pass-through in Thai rice markets. Evidence of noncompetitive rice prices and imperfect pass-through of the exchange rate are found. Our analysis is unique because previous studies have focused on measuring possible price distortion with stocks, management, and domestic subsidies, but this study is the first to analyze exchange rate volatility in Southeast Asian rice trade.

The literature analyzing asymmetrical exchange rate pass-through in food and agriculture is even more limited. Evidence of the first, well-publicized asymmetrical exchange rate pass-through discussion came from Ardeni (1989). Ardeni argues exchange rates should be considered in international trade analysis to see if purchasing parities hold. His paper suggests the law of one price (LOP) may not hold in the long-run when asymmetric exchange rate pass-through is assumed (Ardeni, 1989). Fousekis and Trachanas (2016) study asymmetrical, spatial price linkages in skimmed milk powder markets in trade between the United States, the European Union, and Oceania with a nonlinear auto regressive distributed lag (NARDL) model. Fedoseeva (2014) concludes that exchange rate nonlinearities are more common in food and agriculture trade than non-food trade flows when studying food exports from Europe to the

United States. In a follow up paper, Fedoseeva (2016) expands to say European export quantities are less impacted by exchange rate changes than export values – thus showing a price stabilizer in place for exporters.

This paper relates to the asymmetrical exchange rate pass-through work of Luckstead (2018) and Anders and Fedoseeva (2017), who study cocoa and coffee markets, respectively, discussed in detail in the literature review section. This paper aims to study the impact of exchange rate fluctuations on bilateral trade flows in Southeast Asia. Because Southeast Asian countries have STEs for rice, this analysis will provide insight as to whether these agencies respond to exchange rate fluctuations in a manner consistent with economic theory. Behavior inconsistent with economic theory could provide evidence of stabilizing domestic prices, market power, or export expansion policies. We utilize an NARDL econometric model where the dependent variable is bilateral trade values and independent variables are lagged dependent variables, exchange rates, and real GDP per capita of the importing country.

This analysis focuses on the main Asian importers, by volume, of rice (Malaysia, Indonesia, and China) from one of the largest, by volume, Asian rice exporters (Thailand). Between 2007 and 2014, Thailand, Vietnam, and India accounted for 60% of the world's exports of rice (Glamalva & Weaver, 2015). Thai and Vietnam rice prices are often used as international prices and benchmarks (Hoang & Meyers, 2015). Due to data limitations from Vietnam and reliable data from the Thailand Ministry of Commerce, Thailand is chosen as the exporter. Thailand is a leader in exporting rice and provides clear and detailed export records. Top rice importing countries in Southeast Asia include Indonesia, Malaysia, and the Philippines (Hoang & Meyers, 2015). These three countries account for over 90% of the rice imports in Southeast Asia,[1] and between 2002 and 2018 these countries accounted for 97% of all rice imports in Southeast Asia (FAS, 2020). China is not typically considered part of Southeast Asia; China, however, is a large rice importer, and therefore included in the analysis. China imported more rice in terms of value than Malaysia and Indonesia did from the rest of the world and from Thailand during the study period. Therefore, our analysis includes imports by Malaysia, Indonesia, and China from Thailand. These markets are described in detail below. The remainder of the paper is organized as follows: market information about STEs and each country, next a literature review of related studies, then models followed by data sources and information, results, and conclusion.

1.1 Market Information

1.1.1 State Trading Enterprises

In Southeast Asian rice trade, STEs, which are government control of imports and exports, dominate international trade. Asian governments are greatly concerned with domestic price stability and the influence this has on the many factors shared above, most noticeably self-sufficiency, food security, and political stability. Establishing STEs give these governments more ability to control price fluctuations. STEs are identified by 1) having certain exclusive rights granted to them by the country's government and 2) establishing goals other than profit-maximization (McCorriston & MacLaren, 2012).

Rice is typically omitted from trade negotiations and left to STEs to facilitate. These STEs are granted exclusion from trade agreements by the World Trade Organization (WTO) to solely negotiate rice trade (Glamalva & Weaver, 2015). STEs are present in both importing and exporting markets – however our focus here is importing STEs. For importing markets, STEs

[1] Southeast Asian countries, as classified by the USDA, include Indonesia, Thailand, Vietnam, Burma, Philippines, Cambodia, Laos, and Malaysia (Shean, 2015).

limit market access by implicitly imposing tariff equivalents, import bans, and quantity restrictions.

Hoang and Meyers (2015) implement a partial-equilibrium simulation model to analyze the impact of importing countries eliminating their STE on rice prices. The results show, in Indonesia and Malaysia, retail prices would decrease by 34.3% and increase by 11.3%, respectively. Furthermore, in Thailand, exports would increase by 6%. Overall, the world price of rice would increase by 19.7%, which would benefit producers and hurt consumers. This uncertainty on domestic prices legitimizes these countries' diligence to control rice price. Hoang and Meyers (2015) also observe most STEs operate in heavy importing countries to protect their local markets.

Similar to Hoang and Meyers (2015), Dawe (2000) recognizes a country may protect their rice growers one year from low world prices, but the next year, the country will feel the impact and have to absorb the low prices. Price stabilization is described as the "reduction in the variability of prices without any change in the average level of prices." In an extensive literature review and policy suggestion paper, Dawe (2000) suggests eliminating price stabilizing programs and moving to free trade will increase prices in China by 3.5%. Dawe (2000) found evidence that, like Thailand, Malaysia has been able to successfully stabilize their domestic rice price relative to the world market price. Even with price stabilization, on average, the price stabilization programs in Asia for rice create little difference between the world and domestic prices.

McCorriston and MacLaren (2012) analyze importing countries to measure the trade distortions caused by STEs. A welfare function is defined with variables for producer and consumer surplus, STE profits, and policy weights. The policy weights are adjusted for profit or welfare maximizing simulation to analyze the possibility of changing goals of the STEs and removal of STEs. Their results show STEs act as non-tariff barriers. In the Indonesian rice market specifically, the STE adds 20% to world price to protect domestic producers. For a more detailed history of STEs, see McCorriston and MacLaren (2012). Additionally, for a detailed history of regionalism and rice trade, see Kim & Andres Ramirez (2014).

Given the dominance of STEs in Southeast Asian rice trade, next, we discuss rice trade, STE, and currency regime for Thailand, Malaysia, Indonesia, and China – countries analyzed in this study.

1.1.2 Thailand

Thailand is one of the largest rice producing and exporting countries and rice plays an important role in the Thai economy. About 50%, or 27.7 million acres (11.2 million hectares), of all agricultural land in Thailand is used for rice production. Furthermore, rice production contributed 15% to the agricultural gross domestic product (GDP) in 2018. Thailand ranks sixth in the world in rice production. All exports are responsible for 60% of Thai's GDP and agriculture makes up 20% of exporting generated GDP (Pongsrihadulchai, 2018). While many Southeast Asian rice exporting countries consume a majority of their production domestically, Thailand consumes less than 50% of their total rice production and is therefore a leading rice exporter (Ahmad & Gjølberg, 2015). Thailand has an interest in the world price of rice and their market share.

Thailand has long vied to control the world rice market. In 2002 and 2012, Thailand attempted to establish a council, essentially a rice cartel, with other rice exporters to control rice price (Chen & Saghaian, 2016). However, the rice council was not established, and Thailand was unable to control the world rice price due to other sellers. Thailand again tried to exert control on rice price with the Paddy Pledge Program, enacted from 2011 to 2014. This program provided a loan to farmers to grow their rice (Sirikanchanarak, Liu, Sriboonchitta, & Xie, 2016). At the end of the growing year, they were able to pay back the loan with the rice or money. Farmers typically paid back the loan with their rice since they were offered an artificially high price. Thailand gathered a large stockpile of rice. But according to Sirikanchanarak, Liu, Sriboonchitta, & Xie (2016), the Paddy Pledge Program did not give Thailand full ability to influence the world market. To this day, Thailand's STE – Public Warehouse Organization (PWO) – purchases and sells rice to promote the government price stabilization policy (PWO, 2020).

Rice protection policies might not be good for society in the long-run because when Thailand, Vietnam, or the Philippines impose trade restrictions, the volatility of the world rice market increases. Lee and Valera (2016) point out interdependence across rice trading countries, since most research focuses on time-series data of specific countries. Chen and Saghaian (2016) show Thailand is a major rice exporter, but lacks ability to fully influence the world market by manipulating the world rice price due to other exporters, such as Vietnam and India. These three countries keep each other from monopolizing the market. There is strong cointegration between Thailand and Vietnam because of the large price transmission seen, but it appears Thailand leads price increases (Chen & Saghaian, 2016). John (2013) concludes Thailand's domestic pricing programs are not causing distortion on the global rice market.

Since 1897, the Baht has been the official currency of Thailand (WorldAtlas, 2019). Since 1997, Thailand has had a semi-floating exchange rate or a "managed-float exchange rate regime" in place. The rate is allowed to fluctuate and the Bank of Thailand has authority to step in if imbalances are seen (BoT, 2015).

1.1.3 Malaysia

Malaysia is a net importer of rice, and for 2019, rice imports were estimated at 997,903 metric tons (WTO, 2016). Malaysia allows the importation of rice through its STE, Main Market of Burna Malaysia (BERNAS). BERNAS was privatized in 1996 and acts as the legal entity under direction of the Malaysian government to manage the nation's rice market. BERNAS purchases rice from farmers, processes rice, and distributes rice subsidies to farmers (Kim & Andres Ramirez, 2014). BERNAS is the largest rice miller in Malaysia. Since Malaysia can only supply 60% to 70% of its domestic demand, BERNAS negotiates solely with foreign governments to import rice to fulfill the 30% to 40% of excess demand (BERNAS, 2019a). BERNAS is mandated to perform non-commercial activities for rice importation such as maintaining supply and affordability of rice. Thus, BERNAS does not follow market signals in importing rice. BERNAS specifically indicates they only import long grain milled rice from Thailand (BERNAS, 2019b).

The official currency of Malaysia is the ringgit. From 1998 through July 21, 2005, the ringgit was pegged to the US dollar (USD) (USDoS, 2006). Starting July 22, 2005, the government floated the ringgit.

1.1.4 Indonesia

Indonesia is a leading importer of rice in Southeast Asia. The National Food Logistics Agency (BULOG) is Indonesia's STE governing all food logistics (BULOG, 2018b). In 2000, BULOG was assigned to handle inventory, distribution, and price setting for rice (BULOG, 2018c). Setting the price of rice allows BULOG to encourage farmers to grow more rice to increase supply. BULOG argues the need for food security due to skyrocketing food prices. Since rice is their main staple food and provides needed nutrition, they see the need to manage quantity supplied (BULOG, 2018a). Currently, Indonesia encourages private business to participate in the local rice market, but still maintains the authority to intervene (WTO, 2018b). Since 2005, BULOG has attempted to become more commercial and move towards deregulation. However, an analysis shows their commercialization efforts increase the tariff equivalent they impose on rice imports from 23% to 56% (McCorriston & MacLaren, 2012).

The rupiah has been the official currency of Indonesia since 1946. In the late 1990s, the currency moved from a fixed exchange rate to a free floating rate (Mitchell, 2019).

1.1.5 China

China is the leading rice consumer in the world and is generally a net rice importer. A noticeable spot in China's import data is seen during the early and mid-2000s. In 2003, China exported more rice than it imported because of a large national stock of rice, which reached the highest, historic level of 232,000,000 metric tons (Donglin, 2005). Since then, China has remained a net importer of rice. Estimates show that China imports only 2% of their quantity of consumption (Glamalva & Weaver, 2015). State trading in China became a part of their economy in 1949. The China National Cereals, Oils, and Foodstuffs Corporation (COFCO) has exclusive rights for rice trade. COFCO's goals are to secure an adequate supply of food, limit price fluctuations, and ensure food security. Some non-STE importers are allowed to import to fill demand, but COFCO determines import price. China has stressed to the WTO their STE operates following market theory. China describes in their report to the WTO factors determining their imports are domestic supply, prices of domestic and world rice, and "other factors" (WTO, 2018a). As a result of China's involvement with the WTO, China is trying to move to allow private firms to trade agricultural commodities, but the state still controls most of the trading activities (McCorriston & MacLaren, 2012).

The Chinese Yuan was pegged to the USD from 1994 through July 2005 when it became a managed floating currency exchange rate. China manages the exchange rate, determining the exchange rate for USD daily with room to appreciate or depreciate by pre-determined amounts (Picardo, 2019). According to Picardo (2019), China typically undervalues its currency.

2. Literature Review

Rice trade in Southeast Asia has garnered attention in the agricultural economics literature. Literature on exchange rate and asymmetric exchange rate pass-through for agricultural commodities is relatively new and only a few studies have been conducted. For example, Anders and Fedoseeva (2017) argue that by ignoring asymmetries in exchange rates, trade elasticities may be inaccurate and lead to incorrect trade decisions and policy recommendations. They use an NARDL model to analyze nonlinear exchange rate and income for US coffee imports. Their analysis shows the trade elasticity with respect to exchange rates (LCU/USD) is -1.48 using the auto regressive distributed lag model (ARDL) model and is -1.06 for appreciation and 1.61 for depreciation using the NARDL model for US Arabica coffee imports from Brazil. For US Arabica coffee imports from Guatemala, trade elasticity with respect to exchange rates is -2.48 using the ARDL model and is -3.85 for appreciation and 2.62 for depreciation using the NARDL model. These results highlight the importance of accounting for nonlinearities.

In another recent study, Luckstead (2018) implements an NARDL model to analyze exchange rate volatility in US cocoa bean markets. The results with the respective cocoa varieties are different for the ARDL and NARDL models. For US cocoa imports from Ghana, trade elasticity with respect to exchange rates (USD/LCU) is 0.27 using ARDL model and is

10.70 for appreciation and -16.60 for depreciation using the NARDL model. These results further highlight the importance of accounting for nonlinearities.

Co-movement of export prices via price transmission methods have been studied in Southeast Asia. For example, see Chen and Saghaian (2016) for world rice export markets. Using a threshold vector error correction model, the authors show rice export prices for United States, Thailand, and Vietnam are cointegrated, with the first two countries being the price leaders. John (2013) utilizes a vector autoregression model to analyze if domestic price shocks impact international price and if international price shocks impact domestic price. The results show international price shocks impact domestic price only in the long-run, which implies Thailand rice policies do not heavily distort the international market. Lee and Valera (2016) implement a panel GARCH framework and show price shocks in the Asian rice market transmit to domestic rice price and also impact conditional price variances. The results also show a strong interdependence between Asian rice trading countries. Sirikanchanarak et al. (2016) utilize time-varying copulas and VAR models to analyze price transmission for Thailand and Vietnam rice export prices. The results show these countries' export prices move together, but Vietnam is likely the price leader. Our analysis is unique because it is the first to analyze the impact of exchange rate volatility in Southeast Asian rice trade with asymmetric exchange rates.

3. Econometric Model

Here the equations for estimating the short- and long-run relationships between the value of imports, exchange rate, and importing country GDP are presented. The autoregressive distributed lag (ARDL) is defined first. Then the nonlinear autoregressive distributed lag (NARDL) model is defined.

3.1 ARDL

For each pair of bilateral rice trading partners, the ARDL model is

$$\Delta m_t^k = \alpha^k + \beta^k m_{t-1}^k + \psi_r^k r_{t-1}^k + \psi_i^k i_{t-1}^k + \sum_{n=1}^{N} \phi_n^k \Delta m_{t-n}^k + \sum_{n=1}^{N} \left(\rho_{r,n}^k \Delta r_{t-n}^k + \rho_{\mathrm{i},n}^k \Delta i_{t-n}^k\right) + \xi_t^k, \tag{1}$$

where $\alpha^k, \beta^k, \psi_r^k,\ \psi_i^k, \phi_n^k, \rho_{r,n}^k$, and $\rho_{\mathrm{i},n}^k$ are coefficients; the superscript $k =$ Malaysia, Indonesia, and China represents importing countries; Δ is the first difference; m_t^k is the log of real value of imports by county k from Thailand; r_t^k is the log of the real exchange rate (Baht/LCU) for country k; N is the number of lagged first differences of dependent and independent variables; i_t^k is the log of real per capita income representing domestic demand for country k; and ξ_t^k is the random error term. The error correction term is

$$\beta^k \in [-1,0]$$

and is needed to express long run relationship. If $\beta^k = -1$, then instantaneous long-run equilibrium adjustments occur. If $\beta^k = 0$, then no long-run relationship exists between imports, exchange rates, and income; therefore, the model only estimates short-term dynamics and no cointegration relationship exists. If the variables are cointegrated, a long-run relationship exists. The coefficients ψ_r^k and ψ_i^k are the product of the long-run elasticities (e_r^k and e_i^k) and the error correction term (β^k). Therefore, long-run exchange rate and income pass-through elasticities are calculated by

$$e_r^k = \frac{\psi_r^k}{\beta^k} \text{ and } e_i^k = -\frac{\psi_i^k}{\beta^k}.$$

Standard errors for the elasticities are calculated using the Delta method. Trade elasticities are compared across varieties. The coefficients ϕ_n^k and $\rho_{r,n}^k$ show short-term dynamics, while the coefficients $\rho_{r,0}^{k}$ and $\rho_{i,0}^{k}$ represent contemporaneous elasticities of exchange rates and import demand on trade.

3.2 NARDL

The NARDL model uses the partial sum decomposition of the exchange rate (r^{t}):

$$r_t^k = r_0^k + r_t^{k-} + r_t^{k+}, \tag{2}$$

where r_0^k is the initial value at t_0 and r_t^{k-} and r_t^{k+} are negative and positive first-difference partial sums defined as

$$r_t^{k-} = \sum_{n=1}^{t} \min(\Delta r_n^k, 0) \quad \text{and} \quad r_t^{k+} = \sum_{n=1}^{t} \max(\Delta r_n^k, 0).$$

Using the partial sum decomposition of the exchange rate given by equation (2), the NARDL model is

$$\Delta m_t^k = \alpha_0^k + \beta^k m_{t-1}^k + \psi_r^{k-} r_{t-1}^{k-} + \psi_r^{k+} r_{t-1}^{k+} + \psi_i^k i_{t-1}^k + \sum_{n=1}^{N} \phi_n^k \Delta m_{t-n}^k$$
$$+ \sum_{n=1}^{N} (\rho_{r,n}^{k-} \Delta r_{t-n}^{k-} + \rho_{r,n}^{k+} \Delta r_{t-n}^{k+} + \rho_{i,n}^{k} \Delta i_{t-n}^{k}) + \xi_t^k, \tag{3}$$

where $\alpha_0^k = \alpha^k + r_0^k + i_0^k$. The asymmetrical long-run elasticities for real exchange rates are

$$e_r^{k-} = \frac{\psi_r^{k-}}{\beta^k} \text{ and } e_i^{k+} = -\frac{\psi_i^{k+}}{\beta^k}.$$

4. Data

To econometrically implement the ARDL and NARDL models, we use data on value of imports, real exchange rate, and real gross domestic product (GDP) for importing countries. We collect monthly bilateral quantity and value trade data for Malaysian, Indonesian, and Chinese rice imports from Thailand for harmonized system (HS) codes: 1006 (all rice), 100630 (milled rice, approximately 90% of Thailand's rice exports), and 100640 (broken rice, approximately 10% of Thailand's rice exports) for the period January 2002 through January 2019 from

Thailand's Ministry of Commerce (TMC, 2019).[2] To convert nominal values into real values, we collect consumer price indexes (CPI) on a monthly basis for the importing country from the International Monetary Fund (IMF, 2020). June 2010 is the reference year (=100). Since 2019 CPI had not been reported yet, we estimate one month for January 2019 using average change from previous years along the trend line.

Monthly exchange rate data is collected from the USDA ERS (2019). The value of imports to Malaysia, Indonesia, and China from Thailand is converted to real importing country currency using the CPI and exchange rate data. To obtain the exchange rate between Thailand and Malaysia, Indonesia, and China, we divide Malaysia's, Indonesia's, and China's exchange rate in Local Currency Units per USD (LCU/USD) by Thailand's exchange rate (Baht/USD). Annual GDP per capita in nominal LCU is collected from the World Bank (TWB, 2019). Because of the low variability in each country's GDP data, we estimate the monthly observations from annual real data using spline interpolation via the spine function in R. We also estimate one month for GDP for January 2019 based on previous trends. Descriptive statistics are reported in Tables 1 and 2. Figure 1 shows the exchange rate fluctuations and partial-sum decompositions, based on equation (2), for the three importing countries. Seasonality was identified in Indonesia and Chinese broken rice (HS 100640) imports and removed from the data. Removing seasonality helps ensure the changes in value of imports due to exchange rate fluctuations are captured instead of changes due to seasonality of rice. For example, during harvest season, regardless of exchange rate, STEs may limit rice imports due to a surge in domestic production and lack of storage for rice

[2] We are unable to analyze more detailed rice varieties—10063099 Low Value Long Grain Milled, 10063040 Thai hom mali rice, and 10063030 Glutinousrice (pulot)—due to a lack of data at the 8-digit level.

Table 1 Descriptive Statistics of Real Value of Rice Imports from Thailand in LCU

	Mean	Median	Minimum	Maximum	Standard Deviation
Malaysia (millions)					
1006 Rice	62.933	54.876	2.850	526.361	58.288
100630 Milled Rice	61.038	52.378	2.282	526.361	58.231
100640 Broken Rice	1.442	0.554	0.000	12.424	1.934
Indonesia (billions)					
1006 Rice	164.881	86.203	0.000	1,799.637	244.572
100630 Milled Rice	122.590	26.812	0.000	1,654.533	233.763
100640 Broken Rice	56.188	47.137	0.000	275.002	42.942
China (millions)					
1006 Rice	190.500	153.523	2.962	775.453	141.413
100630 Milled Rice	161.869	130.187	2.929	721.524	128.258
100640 Broken Rice	28.486	14.034	0.018	141.798	32.533

Table 2 Descriptive Statistics of Independent Variables of Importing Countries

	Mean	Median	Minimum	Maximum	Standard Deviation
Exchange Rate (real Baht/LCU)					
Malaysia	13.51	13.09	7.73	20.37	3.64
Indonesia	6.03E-03	5.00E-03	2.18E-03	1.32E-02	3.29E-03
China	6.12	5.89	4.69	8.01	0.83
GDP (real LCU per capita)					
Malaysia	39,573	41,311	27,872	48,319	4,973
Indonesia	41,648,972	45,296,196	23,379,659	59,811,737	11,542,767
China	39,952	41,797	14,273	69,754	16,526

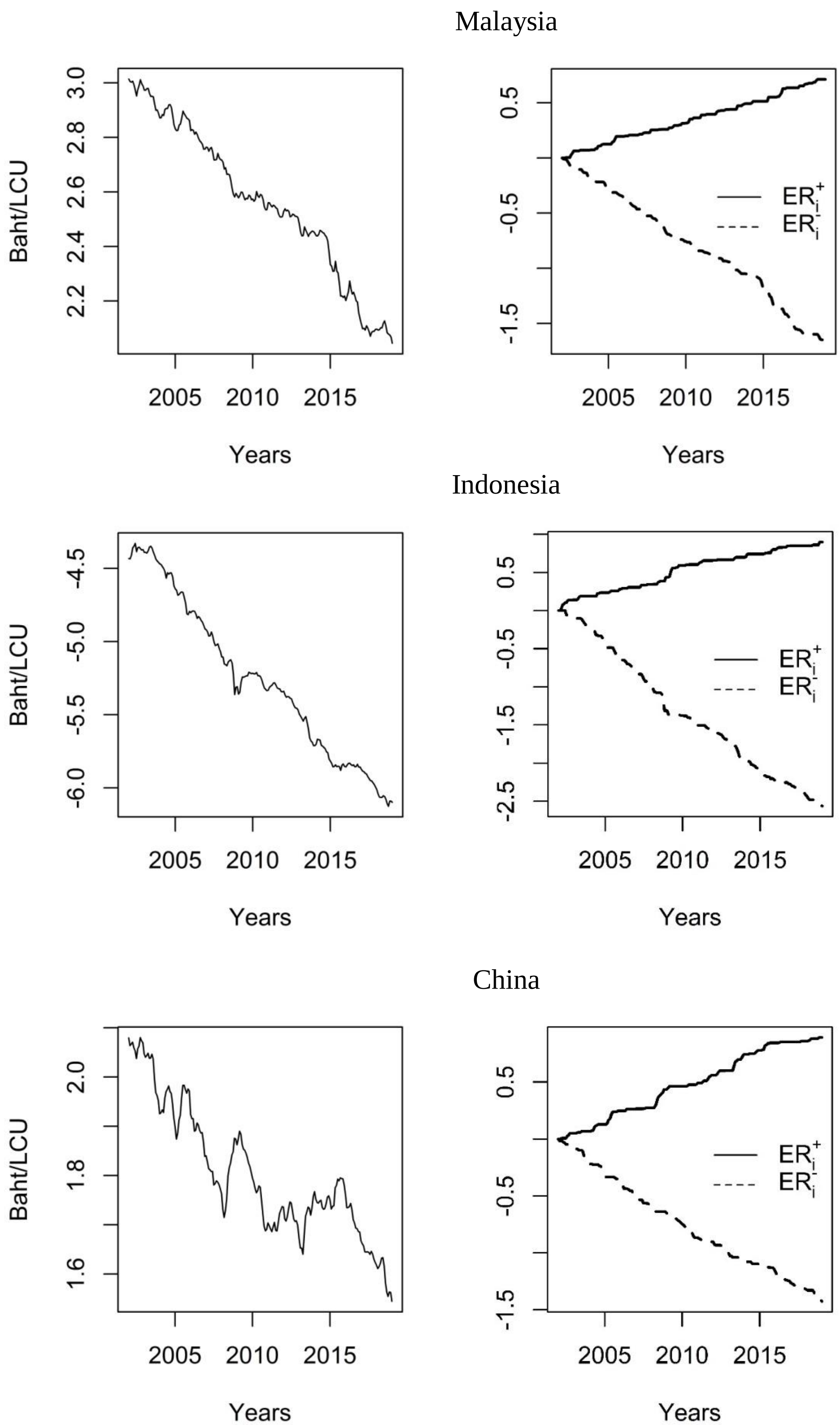

Figure 1 Exchange Rates and Partial Sum Decomposition

We generate indicator variables for the Asian rice crisis and for zeros observed in the data. The Asian or world rice crisis occurred from late 2007 through mid-2008 when prices tripled, and the highest ever world rice price was recorded (Lee & Valera, 2016).[3] Consequently, we create an indicator variable, D1, which takes the value one for rice crisis period and zero otherwise. We only see large spikes in Malaysia to Thailand trade flows of all rice (HS 1006) and milled rice (HS 100630). The indicator variable is included to account for these two outlier months (June and July in 2008). A second indicator variable is included for zeros in value of imports. Because the zeros do not appear to be a part of an overall trend, they could result from months when either i) STEs in the importing country did not import rice or ii) clerical errors occurred in reporting data. In some cases, the former is likely true because it appears the countries stopped importing spontaneously with no trend to zero, potentially providing further evidence of STEs controlling trade. In other cases, the latter is likely true because for some observations very small quantities were reported but trade values were zero. A second indicator variable, D2, is created to control for zeros with one for zero in trade value and zero otherwise. With a sample size of 205 monthly observations, there are 50 zeros in Malaysian import data for broken rice (HS 100640). Indonesian import data has two zeros for all rice (HS 1006), 29 zeros for milled rice (HS 10030), and 9 zeros for broken rice (HS 10040). There are no zeros in the Chinese rice import data. For information on indicator variables included in the models and their lags, see Appendix A. Harvest season of rice was also considered for the importing countries. For example, during rice harvest season, a country may reduce imports of rice because of their increase in supply. However, we added in a harvest variable and it did not impact the results. Our

[3] For a more detailed discussion on causes of the world rice crisis, see Childs & Kiawu, 2009.

final model does not include a harvest variable. We also identified and removed seasonality, as discussed above, so the seasonality of harvest is considered in the final model.

5. Results

Results presented here analyze the pass-through effects of exchange rates to trade values. For the ARDL and NARDL analyses, equations (1) and (3), respectively, are implemented for each country pair and rice variety. The key difference here is the ARDL models do not incorporate asymmetries whereas the NARDL models include the decompositions of the exchange rate.

Exchange rates are the relative price that translates the value of one country's currency into value of another country's currency. Fluctuations in exchange rates impact trade flows. If the state trading enterprises follow economic theory, we hypothesize appreciation of importers' currency (increase in Baht/LCU) will lead to a rise in rice imports and deprecation of importers' currency (decrease in Baht/LCU) will lead to a fall in rice imports.

Tables 3-5 report the long-run exchange rate and income pass-through elasticity results for the ARDL and NARDL models for Malaysian, Indonesian, and Chinese imports from Thailand. Appendix A presents the full regression results for both models of each rice variety for each importing country. The models for each rice variety incorporate lagged dependent variables. We use Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), along with significances of coefficients, as a guide to choosing the number of lags (N).[4] There are consistencies in the optimal number of lags and stated actions of STEs. For example, BERNAS typically buys rice on short term (3-6 months) contracts (WTO, 2016), and the models suggest a three-month lag is ideal for Malaysia. Also, COFCO uses long-term contracts to secure rice

[4] The main conclusions are not sensitive to reasonable changes in the number of lags.

(WTO, 2018a), which is reflective in the larger lags (5-7 months) for the Chinese models. We include indicator variables as discussed in the data section. Note that we report findings both with and without the indicator variables where applicable as a robustness check on the results.

Partial-sum decomposition is not applied to GDP for Indonesia or China because of the strong upward trend. Because Malaysian GDP has more variability, we run the results with the GDP decomposed for the NARDL model. The results and main conclusions (discussed in detail below) did not significantly change when the GDP is decomposed. For consistency in reporting, we do not include the GDP partial-sum decomposition in the main results.

Standard diagnostic tests are used for each model. The Breusch-Godfrey test for serial correlation is implemented. Serial correlation is found in both ARDL and NARDL models for the following importing countries and rice varieties: Malaysia, Indonesia, and China for broken rice; Indonesia for all rice; and China for all rice. To correct the autocorrelation in these models, we employ the Cochrane-Orcutt method. Other diagnostic tests employed include the Ramsey RESET test for misspecification and the Jarque-Bera test for normality. Conclusions indicate a relationship exists between the variables and they are normally distributed. The results of these tests are reported for each model specification in Appendix A. The Pesaran, Shin, and Smith (2001) cointegration test method is also ran to examine long-run equilibrium relationship between the value of imports to the exchange rate and importing country GDP. The F-statistics for each model are reported in the tables and are all above the critical value. This indicates a long-run relationship exists.

Results are discussed below between trading partners by looking at each model, adjusted R^2, exchange rate elasticities, and GDP elasticities for ARDL and NARDL models, calculated using equations (1) and (3).

5.1 Malaysian Imports from Thailand

Results for bilateral trade flows between Malaysia and Thailand are reported in Table 3. The results indicate that, for the ARDL regression, Malaysian imports follow exchange rate theory, but when the exchange rate is decomposed in the NARDL regression, the trade elasticities no longer follow economic theory.

For ARDL all rice (HS 1006), adjusted R^2 ranges from 0.63 to 0.65. For both models, the exchange rate elasticities follow economic theory and are statistically significant and inelastic as a 1% increase in the exchange rate leads to a 0.90% and 0.80% change in trade values for models 1 and 2, respectively. The GDP results suggest rice is a normal good, because an increase in income would increase purchases of rice. The results show a 1% increase in GDP leads to a 2.06% and 1.69% increase in value of imports.

For NARDL all rice, the adjusted R^2 is 0.65 for both models. With the decomposed exchange rate, the results differ from the ARDL model. With asymmetrical exchange rates, the results no longer follow economic theory – which states when LCU appreciates (depreciates), imports should increase (decrease). The results show a 1% increase in exchange rate leads to a 6.70% and 6.85% decrease in the value of trade for Models 1 and 2, respectively, and are statistically significant. Also, theory is not followed when deprecation occurs. A 1% decrease in exchange rate leads to a 1.92% and 1.97% increase in value of imports, both significant. This would signify BERNAS is not optimizing import decisions as exchange rates fluctuate; however, these results could indicate an alternative motive of price stability.

Table 3 Malaysian Imports from Thailand Results

1006 Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[c]	Elasticity	P	F-statistic[c]
ARDL Model						
ER	0.90	0.02	79.40	0.80	0.04	76.05
GDP	2.06	0.02	79.40	1.69	0.05	76.05
NARDL Model						
ER^+	-6.70	0.01	79.68	-6.85	0.01	83.73
ER^-	-1.92	0.06	79.68	-1.97	0.05	83.74
GDP	3.44	0.00	79.68	3.44	0.00	83.71

[a] value lagged 3 times, ER and GDP lagged once with indicator variable (IV) for world rice crisis; [b] value lagged 3 times, ER and GDP lagged once without IV; [c] ARDL Model 1 critical value of 10% = 2.99, ARDL Model 2 critical value of 10% = 3.06, NARDL critical value of 10% = 2.94

100630 Milled Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[c]	Elasticity	P	F-statistic[c]
ARDL Model						
ER	0.88	0.02	84.54	0.78	0.05	80.83
GDP	2.17	0.01	84.54	1.81	0.04	80.83
NARDL Model						
ER^+	-6.89	0.01	85.34	-7.07	0.01	89.08
ER^-	-2.00	0.05	85.34	-2.07	0.04	89.08
GDP	3.59	0.00	85.34	3.59	0.00	89.06

[a] value lagged 3 times, ER and GDP lagged once with IV for world rice crisis; [b] value lagged 3 times, ER and GDP lagged once without IV; [c] ARDL Model 1 critical value of 10% = 2.99, ARDL Model 2 critical value of 10% = 3.06, NARDL critical value of 10% = 2.94

Table 3 Continued

100640 Broken Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[c]	Elasticity	P	F-statistic[c]
ARDL Model						
ER	8.91	0.10	1031.11	4.64	0.51	14.34
GDP	17.71	0.15	1030.45	0.07	1.00	14.34
NARDL Model						
ER^+	27.98	0.59	13.69	28.23	0.58	13.79
ER^-	12.56	0.54	13.66	12.64	0.53	13.77
GDP	-7.31	0.70	13.77	-7.39	0.70	13.88

[a] value lagged 3 times, ER and GDP lagged once with IV for zeros; [b] value lagged 3 times, ER and GDP lagged once without IV; [c] ARDL Model 1 critical value of 10% = 2.99, ARDL Model 2 critical value of 10% = 3.06, ARDL critical value of 10% = 2

According to economic theory, appreciation (depreciation) in an importing country will lead to inflation (deflation). However, expanding imports when exchange rate rises and shrinking imports when the exchange rate falls will dampen the domestic price fluctuations associated with exchange rate volatility. Therefore, these results suggest that BERNAS is using imports to stabilize domestic prices, which is one of BERNAS's long-stated objectives (Kim & Andres Ramirez, 2014). These results also highlight the importance of the NARDL model to analyze exchange rate volatility as these results are not uncovered until nonlinearities are included.

As for GDP, according to both Models 1 and 2, a 1% rise in income in Malaysia leads to a 3.44% increase in imports, which is more elastic than in the ARDL models. This counters past arguments that rice is an inferior good. Some possible explanations for this are an increase in income allows people to purchase higher quality aromatic and fragrant rice varieties, possibly seen as normal or luxury food items. BERNAS may be aware of these preferences and expands imports of higher quality rice as income increases.

The results for ARDL and NARDL milled rice (HS 100630) are slightly more elastic than the models for all rice, which is not surprising because milled rice accounts for 90% of traded rice. For example, for NARDL Model 1, the appreciation coefficient decreases from -6.70% to -6.89% and the depreciation coefficient becomes more negative from -1.92% to -2.00%. The evidence remains that BERNAS is dampening price fluctuations by acting opposite of the market.

For broken rice (HS 100640), the estimated coefficients lack statistical significance. For ARDL broken rice, adjusted R^2 ranges from 0.64 to 0.96 for both models. Adjusted R^2 is 0.64 for both NARDL models. These coefficients are highly insignificant, but consistent between the models. These results may indicate that BERNAS may take advantage of favorable exchange rate when purchasing broken rice. It is important to remember that broken rice accounts for only 10% of traded rice. Broken rice has the highest adjusted R^2. This may show that there is less manipulation in trading of broken rice since normal economic factors account for such a large part of why rice was traded.

5.2 Indonesian Imports from Thailand

Results for bilateral trade flows between Indonesia and Thailand are reported in Table 4. In contrast to bilateral trade flows between Malaysia and Thailand, the results for trade between Indonesia and Thailand generally follow economic theory. A possible explanation could be that Indonesia's STE, BULOG, or private importers generally follow exchange rate theory when making import decisions; however, all but three elasticities with milled rice reported lack statistical significance.[5] Therefore, while BULOG's import decisions are generally consistent with theory, it is difficult to fully interpret import actions.

For ARDL all rice (HS 1006), the adjusted R^2 ranges from 0.68 to 0.93. The NARDL models for all rice show the estimated exchange rate elasticity is positive but insignificant, and for GDP, the elasticity is inelastic, although insignificant. The adjusted R^2 ranges from 0.67 to 0.93 for the NARDL models.

[5] As a sensitivity analysis, several models are run with various lags on value of imports, exchange rate, and GDP, and the results are generally consistent.

Table 4 Indonesian Imports from Thailand Results

1006 Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[c]	Elasticity	P	F-statistic[c]
ARDL Model						
ER	1.76	0.45	661.74	1.66	0.36	77.32
GDP	4.06	0.33	661.73	3.78	0.25	77.32
NARDL Model						
ER^+	7.12	0.36	657.23	10.33	0.15	78.06
ER^-	2.22	0.34	656.80	2.75	0.17	78.04
GDP	0.86	0.90	656.02	-0.50	0.92	78.06

[a] value lagged 3 times, ER and GDP lagged once with IV for zeros; [b] value lagged 3 times, ER and GDP lagged once without IV; [c] ARDL Model 1 critical value of 10% = 2.99, ARDL Model 2 critical value of 10% = 3.06, NARDL critical value of 10% = 2.94

100630 Milled Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[d]	Elasticity	P	F-statistic[d]
ARDL Model						
ER	1.04	0.55	479.96	9.76	0.10	66.26
GDP	-0.59	0.85	479.96	10.21	0.34	66.26
NARDL Model						
ER^+	9.46	0.73	60.76	0.60	0.98	69.17
ER^-	13.14	0.07	60.63	11.39	0.08	69.11
GDP	20.95	0.23	60.53	23.11	0.16	68.83

[a] ARDL - value lagged 3 times, ER and GDP lagged once with IV for zeros and NARDL - value lagged 3 times, ER and GDP lagged 4 times without IV; [b] value lagged 3 times, ER and GDP lagged once without IV; [c] ARDL Model 1 critical value of 10% = 2.99, ARDL Model 2 critical value of 10% = 3.06, NARDL critical value of 10% = 2.94

Table 4 Continued

100640 Broken Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[c]	Elasticity	P	F-statistic[c]
ARDL Model						
ER	2.19	0.34	1159.48	5.16	0.23	1084.34
GDP	5.70	0.17	1163.55	13.39	0.09	1083.97
NARDL Model						
ER^{+}	11.7	0.14	1120.74	12.98	0.35	1033.52
ER^{-}	2.88	0.20	1124.35	4.88	0.26	1046.59
GDP	-0.44	0.94	1109.89	6.24	0.62	1038.56

[a] value lagged 3 times, ER and GDP lagged once with IV for zeros; [b] value lagged 3 times, ER and GDP lagged once without IV; [c] ARDL Model 1 critical value of 10% = 2.99, ARDL Model 2 critical value of 10% = 3.06, NARDL critical value of 10% = 2.94

More significant results come from milled rice (HS 100630) and suggest theory is followed. For ARDL milled rice, the adjusted R^2 ranges from 0.63 to 0.90. For Model 2, where the exchange rate coefficient follows economic theory and is significant, a 1% appreciation leads to a 9.76% increase in imports. For NARDL milled rice models, adjusted R^2 ranges from 0.64 to 0.66. The exchange rate coefficients follow economic theory, a 1% decrease in exchange rate leads to a 13.14% and 11.39% decrease in imports, both are significant. The exchange rate results for milled rice are more elastic than the results for all rice. These results suggest that BULOG decreases imports with depreciation, in line with theory. When GDP increases, Indonesia consumes more rice. These numbers may indicate Indonesia has unmet demand for rice until the people's incomes increase and they can afford it.

As with the other countries' results, imports of broken rice (HS 100640) to Indonesia lack significance. For ARDL broken rice, adjusted R^2 ranges from 0.95 to 0.97. A 1% increase in income leads to a 13.39% increase of import value in Model 2. This counters other income elasticities and literature which suggest that broken rice is an inferior product. For the NARDL model for broken rice, the adjusted R^2 ranges from 0.95 to 0.97. The asymmetrical exchange rate analysis confirms the results of the ARDL model, but reveals that appreciation is more elastic than depreciation.

While lacking in significance, the exchange rate variables follow theory. This proves the stated goal of Indonesia's STE, BULOG, to allow non-government entities to participate in the rice market. These results may also imply BULOG makes more ad hoc decisions in rice trade compared to Malaysia (discussed above) and China (discussed below), intervening when they deem necessary as discussed in the introduction.

5.3 Chinese Imports from Thailand

Results for bilateral trade flows between China and Thailand are reported in Table 5. Chinese imports appear to follow theory in five of the six ARDL models, but again we see the decomposition of exchange rate providing a different story. The findings below describe how COFCO does not focus on profit-maximization and may focus on actions opposite of theory. Operating opposite of theory may be an attempt to keep the price from changing drastically. While Malaysia had the most significant results and Indonesia suffered from lack of significant results, the results for China fall between with significance. In general, the results show the estimated coefficients in the ARDL models lack significance while they are generally more significant in the NARDL models.

For the ARDL models for all rice (HS 1006), adjusted R^2 ranges from 0.73 to 0.86. An increase in income of 1% causes a 0.64% increase in imports in Model 2, showing the income elasticity is inelastic. The NARDL models for all rice again reveal asymmetries in the elasticities. The adjusted R^2 ranges from 0.75 to 0.87. The exchange rate elasticities for depreciation do not follow theory and are significant. A 1% depreciation in the exchange rate cause imports to rise by 5.24% and 5.00% for Model 1 and Model 2, respectively. Thus, COFCO does not respond to appreciation by increasing imports when their currency depreciations. This could imply that COFCO is more concerned with providing a steady supply of rice to Chinese consumers than optimizing purchasing power, particularly when the Yuan depreciates. The increase in magnitude on an exchange rate coefficient from the ARDL to NARDL model shows the importance of the NARDL model. GDP coefficients change signs from the ARDL to NARDL models. The elasticities are significant but suggest rice is an inferior good in China. A 1% increase in income leads to a 4.55% and 3.86% decrease of rice imports.

Table 5 Chinese Imports from Thailand Results

1006 Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic[c]	Elasticity	P	F-statistic[c]
ARDL Model						
ER	1.3	0.56	15.28	0.05	0.97	70.52
GDP	0.86	0.16	15.08	0.64	0.04	70.52
NARDL Model						
ER^+	0.72	0.69	19.7	0.17	0.87	84.18
ER^-	-5.24	0.06	19.53	-5.00	0.00	84.14
GDP	-4.55	0.02	19.46	-3.86	0.00	84.09

[a] value lagged 5 times, ER and GDP lagged once without IV; [b] value lagged 7 times, ER and GDP lagged once without IV; [c] critical value of 10% = 2.94

100630 Milled Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic	Elasticity	P	F-statistic
ARDL Model						
ER	-0.17	0.9	73.52	1.94	0.19	70.21
GDP	0.3	0.4	73.52	0.75	0.05	70.21
NARDL Model						
ER^+	-0.09	0.94	80.64	-0.06	0.95	81.28
ER^-	-4.47	0.01	80.69	-4.42	0.01	81.28
GDP	-3.52	0.01	80.67	-3.48	0.00	81.26

[a] value lagged 5 times, ER and GDP lagged once without IV; [b] ARDL - value, ER, and GDP lagged 5 times without IV and NARDL - value lagged 6 times, ER and GDP lagged once without IV; [c] critical value of 10% = 2.94

Table 5 Continued

100640 Broken Rice						
	Model 1[a]			Model 2[b]		
	Elasticity	P	F-statistic	Elasticity	P	F-statistic
ARDL Model						
ER	3.75	0.44	5.93	3.00	0.48	7.12
GDP	3.98	0.00	5.75	3.79	0.00	6.9
NARDL Model						
ER^+	3.88	0.41	6.17	3.26	0.42	7.63
ER^-	-0.37	0.96	5.98	-1.81	0.76	7.37
GDP	0.33	0.95	5.94	-0.51	0.90	7.33

[a] value lagged 5 times, ER and GDP lagged once without IV; [b] value lagged 7 times, ER and GDP lagged once without IV; [c] critical value of 10% = 2.94

While rice is an important food commodity, rice being an inferior good could be consistent with the strong growth of the middle class, which increased by about 775%, from about 80 million in 2002 to about 700 million by 2019 (Statista, 2019). This growing middle class may prefer meat over rice.

For the ARDL models for milled rice (HS 100630), the adjusted R^2 for both models is 0.73. The result for GDP in Model 2 shows that an increase in income of 1% causes a 0.75% increase in imports. For the NARDL models for milled rice, the adjusted R^2 ranges from 0.74 to 0.75. Depreciation of exchange rate does not follow theory, where a 1% decrease in exchange rate leads to a 4.47% and 4.42% increase in imports and are both significant. These results confirm our initial idea that COFCO is not acting rational. This is consistent with our conclusion for all rice (HS 1006) – COFCO focuses on providing a steady supply of rice to Chinese consumers and is not concerned with optimizing purchasing power. Again, GDP coefficients are significant, but suggest rice is an inferior good in China. For both HS 1006 and 100630 rice designations, when income increases, and the coefficients are significant, imports of rice decrease for the NARDL models. For milled rice, a 1% increase in income leads to a 3.52% and 3.48% decrease of rice imports.

For the ARDL models for broken rice (HS 100640), the adjusted R^2 is 0.80. Broken rice does exhibit consistency in the exchange rate elasticity estimates. A 1% increase of income leads to a 3.98% and 3.79% increase in imports. The GDP elasticity estimates are the only significant results in the broken rice analysis, possibly showing that broken rice could be a normal good. The adjusted R^2 for both NARDL models is 0.80. Overall, the NARDL models suggest changes in GDP largely do not impact broken rice import decisions.

5.4 Summary

The results tell an interesting story which largely depends on the type of rice and which country is importing. Consistency is lacking when comparing results among the three importing countries, which shows how heavily governments in Asia are involved in rice importing. In many cases, fluctuations in exchange rates do not impact import decisions as they should. Rice is treated somewhat similar in Malaysia and China. Indonesia provides different results showing importers (commercial and STE) are more responsive to exchange rate fluctuations. In analyzing imports, generally the best results are from milled rice. One would assume this because the results for all rice include broken rice, which is minimally traded. Across all three trading partners of Thailand, broken rice is not highly traded. Broken rice appears to be an inferior good. Broken rice also has the highest adjusted R^2. This may show there is less manipulation in trading of broken rice since normal economic factors account for such a large part of why it is traded. This rice variety may not hold a lot of intrinsic value to Asians, because they do not appear to be protecting it. The price elasticity of rice demand has been thought to be inelastic in Asian countries and we found some evidence to support this. The lack of significance in models shows behavior where there is no rational, economic thought exhibited since import decisions are not impacted by exchange rate volatility.

6. Conclusion

Rice is an important crop, specifically in Southeast Asia. Large rice consuming countries often import rice to fill their domestic demand, but have the goal of being self-sufficient. Rice is thinly traded, only about 8% of total rice production enters the international market; consequently, international rice prices fluctuate greatly with supply shocks due to drought or trade restrictions by rice exporting countries. Furthermore, government intervention in domestic rice markets may destabilize the international rice market. Price stability is a major focus of Asian governments since rice price fluctuation impacts self-sufficiency, food security, and political stability. With this shared concern in Southeast Asia of unfair rice prices, many have opted to create an STE. In the Southeast Asian rice trade, STEs control a majority of trade in importing countries since the government grants STEs control of trade. Some of the goals of STEs are food security, farmer support, political stability, self-sufficiency, and maintaining culture norms. The goals of an STE differ from profit-maximizing trade agencies, and therefore these may prohibit rice markets to respond to price fluctuations.

The literature analyzing exchange rate pass-through in food and agriculture is limited, particularly for rice trade in Asia. There is extended literature on exchange rate pass-through for non-agricultural commodities, such as oil. Within agriculture, only a handful of research papers exist. The literature analyzing asymmetrical exchange rate pass-through in food and agriculture is even more limited. This analysis is unique because previous studies have focused on measuring possible price distortion with stocks, management, and domestic subsidies, but this study is the first to analyze exchange rate volatility in Southeast Asian rice trade.

This paper aims to study the impact of exchange rate fluctuations on bilateral trade flows in Southeast Asia. Because Southeast Asian countries have STEs for rice, this analysis provides insight that these agencies do not respond to exchange rate fluctuations in a manner consistent with economic theory. Behavior inconsistent with economic theory could provide evidence of stabilizing domestic prices, market power, or export expansion policies. We utilize an NARDL econometric model where the dependent variable is bilateral trade values and independent variables are lagged dependent variables, exchange rates, and real GDP per capita of the importing country. Our analysis focuses on imports by Malaysia, Indonesia, and China from Thailand.

The results confirm our anticipations – STEs do not follow theory when importing rice. Rice is treated somewhat similar in Malaysia and China. Indonesia provided different results showing their STE may not exert as much power as the others. Malaysia's BERNAS appears to be acting irrational when importing rice. BULOG in Indonesia derives its actions from market signals, however the insignificance here cautions the assumption they are acting according to theory. China's COFCO looks at other signals to import rice. We do see clear confirmation the NARDL model provides the best analysis. We can conclude that rice is not viewed as a normal commodity. Our results show these countries do not operate by optimizing rice imports as purchasing power fluctuates. Instead, restricting or increasing imports may be a tool to stabilize domestic prices – since opposite of theory actions occur.

Limitations of this study include lack of significance in some country pairs. We also analyze the years 2002 through 2019, where many STEs had changing goals and programs. Also, Southeast Asian countries have high storage costs due to lack of space and hot, humid climates that may prevent them from importing when the price is favorable.

This study highlights the importance of the NARDL to model exchange rate volatility as these results are not uncovered until nonlinearities are included. This research can be used to study STEs and provide information on their actions. Findings here can support policy and trade decisions for rice importing and exporting countries to operate with STE countries. Future studies include looking at Vietnam as the main exporter or looking at the impacts of changing goals of STEs over time.

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8. Appendix A Regression Results for Bilateral Trade Flows

Table A 1 Regression Results for Malaysia from Thailand ARDL 1006 All Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-3.48	5.37	-1.22	5.48
m_{t-1}^{k}	-0.54	0.04	-0.55	0.04
r_{t-1}^{k}	0.49	0.22	0.44	0.22
i_{t-1}^{k}	1.12	0.47	0.92	0.48
Δm_{t-1}^{k}	0.31	0.05	0.31	0.05
Δm_{t-2}^{k}	0.31	0.05	0.27	0.05
Δr_{t}^{k}	0.84	2.00	0.15	2.05
Δi_{t}^{k}	-1.79	4.49	-6.13	4.44
$\Delta \mathrm{D1}_{t-2}$	1.12	0.32		
Adj. R^2	0.65		0.63	
F-Value	46.86		48.96	
Deg. Fr.	193.00		194.00	
BG	0.31		0.73	
RESET	0.00		0.00	
J.B.	0.02		0.07	

Table A 2 Regression Results Malaysia from Thailand NARDL 1006 All Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-10.47	5.77	-10.3	5.75
m_{t-1}^{k}	-0.58	0.05	-0.57	0.04
r_{t-1}^{k+}	-3.9	1.53	-3.93	1.53
r_{t-1}^{k-}	-1.12	0.6	-1.13	0.59
i_{t-1}^{k}	2	0.57	1.97	0.57
Δm_{t-1}^{k}	0.32	0.05	0.32	0.05
Δm_{t-2}^{k}	0.27	0.04	0.27	0.04
Δr_{t}^{k+}	6.69	4.44	6.57	4.43
Δr_{t}^{k-}	-6.06	3.12	-5.94	3.11
Δi_{t}^{k}	-3.79	4.61	-4.8	4.34
$\Delta \mathrm{D1}_{t}$	0.22	0.33		
Adj. R^2	0.65		0.65	
F-Value	37.58		41.83	
Deg. Fr.	191.00		192.00	
BG	0.25		0.40	
RESET	0.00		0.00	
J.B.	0.17		0.16	

Table A 3 Regression Results for Malaysia from Thailand ARDL 100630 Milled Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-4.24	5.53	-1.96	5.65
m_{t-1}^{k}	-0.56	0.04	-0.57	0.04
r_{t-1}^{k}	0.50	0.22	0.44	0.23
i_{t-1}^{k}	1.22	0.48	1.02	0.49
Δm_{t-1}^{k}	0.31	0.05	0.30	0.05
Δm_{t-2}^{k}	0.31	0.05	0.27	0.05
Δr_{t}^{k}	0.96	2.06	0.25	2.11
Δi_{t}^{k}	-2.50	4.63	-6.93	4.58
$\Delta \mathrm{D1}_{t-2}$	1.14	0.33		
Adj. R^2	0.66		0.64	
F-Value	48.75		51.09	
Deg. Fr.	193.00		194.00	
BG	0.22		0.49	
RESET	0.00		0.00	
J.B.	0.01		0.04	

Table A 4 Regression Results for Malaysia from Thailand NARDL 100630 Milled Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-11.85	5.94	-11.62	5.93
m_{t-1}^{k}	-0.60	0.05	-0.59	0.04
r_{t-1}^{k+}	-4.15	1.57	-4.19	1.57
r_{t-1}^{k-}	-1.21	0.61	-1.23	0.61
i_{t-1}^{k}	2.17	0.59	2.13	0.59
Δm_{t-1}^{k}	0.32	0.05	0.31	0.05
Δm_{t-2}^{k}	0.27	0.04	0.28	0.04
Δr_{t}^{k+}	6.87	4.56	6.73	4.55
Δr_{t}^{k-}	-6.16	3.21	-6.01	3.20
Δi_{t}^{k}	-4.32	4.75	-5.55	4.47
$\Delta \mathrm{D1}_{t}$	0.26	0.34		
Adj. R^2	0.66		0.66	
F-Value	39.34		43.74	
Deg. Fr.	191.00		192.00	
BG	0.15		0.26	
RESET	0.00		0.00	
J.B.	0.12		0.11	

Table A 5 Regression Results for Malaysia from Thailand ARDL 100640 Broken Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-235.05	163.32	-0.54	24.12
m_{t-1}^{k}	-1.18	0.03	-0.13	0.03
r_{t-1}^{k}	10.50	6.42	0.62	0.96
i_{t-1}^{k}	20.87	14.64	0.01	2.08
Δm_{t-1}^{k}	0.27	0.02	0.64	0.05
Δm_{t-2}^{k}	0.54	0.03	-0.16	0.05
Δr_{t}^{k}	3.12	7.49	-8.77	11.36
Δi_{t}^{k}	62.61	26.23	50.60	21.31
$\Delta \mathrm{D2}_{t-2}$	-4.86	0.51		
Adj. R^2	0.96		0.64	
F-Value	618.80		52.40	
Deg. Fr.	193.00		194.00	
BG	0.05		0.00	
RESET	0.70		0.01	
J.B.	0.00		0.00	

Table A 6 Regression Results for Malaysia from Thailand NARDL 100640 Broken Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	11.62	26.12	11.71	26.04
m_{t-1}^{k}	-0.13	0.03	-0.13	0.03
r_{t-1}^{k+}	3.71	6.84	3.73	6.81
r_{t-1}^{k-}	1.66	2.69	1.67	2.68
i_{t-1}^{k}	-0.97	2.52	-0.98	2.51
Δm_{t-1}^{k}	0.65	0.05	0.65	0.05
Δm_{t-2}^{k}	-0.17	0.07	-0.17	0.05
Δr_{t}^{k+}	-31.60	26.90	-31.80	26.77
Δr_{t}^{k-}	5.84	18.10	6.05	17.95
Δi_{t}^{k}	47.87	21.56	47.79	21.50
$\Delta \mathrm{D2}_{t-2}$	-0.09	0.79		
Adj. R^2	0.64		0.64	
F-Value	36.50		40.70	
Deg. Fr.	190.00		191.00	
BG	0.00		0.00	
RESET	0.01		0.04	
J.B.	0.00		0.00	

Table A 7 Regression Results for Indonesia from Thailand ARDL 1006 All Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-40.26	67.32	-17.62	25.72
m_{t-1}^{k}	-1.08	0.03	-0.54	0.04
r_{t-1}^{k}	1.90	2.49	0.89	0.99
i_{t-1}^{k}	4.39	4.55	2.02	1.76
Δm_{t-1}^{k}	0.32	0.02	0.40	0.05
Δm_{t-2}^{k}	0.44	0.03	0.14	0.05
Δr_{t}^{k}	-5.89	3.42	-6.00	5.71
Δi_{t}^{k}	8.68	9.68	2.03	16.15
$\Delta \mathrm{D2}_{t-2}$	-9.36	1.08		
Adj. R^2	0.93		0.68	
F-Value	344.40		60.51	
Deg. Fr.	192.00		194.00	
BG	0.03		0.88	
RESET	0.00		0.00	
J.B.	0.00		0.00	

Table A 8 Regression Results for Indonesia from Thailand NARDL 1006 All Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	9.50	121.27	16.99	46.18
m_{t-1}^{k}	-1.08	0.03	-0.54	0.04
r_{t-1}^{k+}	7.69	8.40	5.59	3.91
r_{t-1}^{k-}	2.40	2.54	1.49	1.09
i_{t-1}^{k}	0.92	7.16	-0.27	2.73
Δm_{t-1}^{k}	0.32	0.02	0.39	0.05
Δm_{t-2}^{k}	0.44	0.03	0.15	0.05
Δr_{t}^{k+}	2.68	8.98	5.08	14.05
Δr_{t}^{k-}	-8.67	4.66	-11.26	8.05
Δi_{t}^{k}	8.04	10.09	1.98	16.17
$\Delta \mathrm{D2}_{t-2}$	-9.32	1.08		
Adj. R^2	0.93		0.67	
F-Value	273.70		47.19	
Deg. Fr.	190.00		192.00	
BG	0.03		0.79	
RESET	0.00		0.00	
J.B.	0.00		0.00	

Table A 9 Regression Results for Indonesia from Thailand ARDL 100630 Milled Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	34.67	39.85	-50.91	75.02
m_{t-1}^{k}	-0.87	0.03	-0.48	0.04
r_{t-1}^{k}	0.91	1.54	4.66	2.89
i_{t-1}^{k}	-0.52	2.72	4.87	5.12
Δm_{t-1}^{k}	-0.10	0.03	0.20	0.05
Δm_{t-2}^{k}	0.97	0.04	0.37	0.04
Δr_{t}^{k}	-0.57	8.77	-15.33	16.53
Δi_{t}^{k}	-11.11	25.13	-62.44	47.32
$\Delta \mathrm{D2}_{t-2}$	-21.10	0.94		
Adj. R^2	0.90		0.63	
F-Value	219.77		50.22	
Deg. Fr.	193.00		194.00	
BG	0.39		0.73	
RESET	0.00		0.00	
J.B.	0.00		0.00	

Table A 10 Regression Results for Indonesia from Thailand NARDL 100630 Milled Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	-153.36	136.63	Intercept	-178.85	133.94
m_{t-1}^{k}	-0.46	0.04	m_{t-1}^{k}	-0.48	0.04
r_{t-1}^{k+}	4.31	12.31	r_{t-1}^{k+}	0.29	11.22
r_{t-1}^{k-}	5.99	3.36	r_{t-1}^{k-}	5.50	3.12
i_{t-1}^{k}	9.55	8.09	i_{t-1}^{k}	11.16	7.93
Δm_{t-1}^{k}	0.22	0.06	Δm_{t-1}^{k}	0.21	0.05
Δm_{t-2}^{k}	0.35	0.05	Δm_{t-2}^{k}	0.37	0.04
Δr_{t}^{k+}	94.17	64.09	Δr_{t}^{k+}	70.29	40.19
Δr_{t}^{k-}	-99.89	39.96	Δr_{t}^{k-}	-51.82	23.12
Δi_{t}^{k}	-223.36	80.50	Δi_{t}^{k}	-58.38	46.71
Δr_{t-1}^{k+}	-26.65	62.08			
Δr_{t-1}^{k-}	73.69	41.02			
Δi_{t-1}^{k}	185.16	83.82			
Δr_{t-2}^{k+}	-22.78	61.34			
Δr_{t-2}^{k-}	6.44	40.14			
Δi_{t-2}^{k}	-78.45	83.46			
Δr_{t-3}^{k+}	32.39	39.05			
Δr_{t-3}^{k-}	-38.14	24.77			
Δi_{t-3}^{k}	15.38	50.09			
Adj. R^2	0.66			0.64	
F-Value	22.44			40.94	
Deg. Fr.	182.00			192.00	
BG	0.20			0.98	
RESET	0.00			0.00	
J.B.	0.00			0.00	

Table A 11 Regression Results for Indonesia from Thailand ARDL 100640 Broken Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	-72.16	67.91	-233.94	150.25
m_{t-1}^{k}	-1.12	0.02	-1.27	0.03
r_{t-1}^{k}	2.44	2.55	6.54	5.48
i_{t-1}^{k}	6.37	4.62	16.99	10.10
Δm_{t-1}^{k}	0.18	0.02	0.37	0.02
Δm_{t-2}^{k}	0.67	0.03	0.33	0.02
Δr_{t}^{k}	-3.11	5.09	-2.57	6.63
Δi_{t}^{k}	22.67	15.58	48.65	19.49
$\Delta \mathrm{D2}_{t-2}$	-14.14	1.03		
Adj. R^2	0.97		0.95	
F-Value	755.30		586.30	
Deg. Fr.	192.00		193.00	
BG	0.46		0.00	
RESET	0.00		0.00	
J.B.	0.00		0.00	

Table A 12 Regression Results for Indonesia from Thailand NARDL 100640 Broken Rice

	Model 1		Model 2	
	Estimate	Standard Error	Estimate	Standard Error
Intercept	32.33	112.89	-109.47	266.98
m_{t-1}^{k}	-1.11	0.02	-1.27	0.03
r_{t-1}^{k+}	13.01	8.81	16.41	17.57
r_{t-1}^{k-}	3.21	2.52	6.18	5.47
i_{t-1}^{k}	-0.49	6.67	7.90	15.76
Δm_{t-1}^{k}	0.18	0.02	0.37	0.02
Δm_{t-2}^{k}	0.68	0.03	0.33	0.02
Δr_{t}^{k+}	-0.22	13.18	-7.82	17.82
Δr_{t}^{k-}	-2.52	7.26	1.74	9.07
Δi_{t}^{k}	19.96	15.86	43.54	20.39
$\Delta \mathrm{D2}_{t-2}$	-14.36	1.04		
Adj. R^2	0.97		0.95	
F-Value	584.80		450.20	
Deg. Fr.	190.00		191.00	
BG	0.43		0.00	
RESET	0.00		0.00	
J.B.	0.00		0.00	

Table A 13 Regression Results for China from Thailand ARDL 1006 All Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	0.88	1.24	Intercept	5.33	2.46
m_{t-1}^{k}	-0.12	0.02	m_{t-1}^{k}	-0.45	0.04
r_{t-1}^{k}	0.16	0.26	r_{t-1}^{k}	0.02	0.52
i_{t-1}^{k}	0.10	0.07	i_{t-1}^{k}	0.29	0.15
Δm_{t-1}^{k}	0.95	0.05	Δm_{t-1}^{k}	0.43	0.05
Δm_{t-2}^{k}	-0.75	0.06	Δm_{t-2}^{k}	-0.16	0.06
Δm_{t-3}^{k}	0.49	0.06	Δm_{t-3}^{k}	0.14	0.06
Δm_{t-4}^{k}	-0.14	0.03	Δm_{t-4}^{k}	0.10	0.05
Δr_{t}^{k}	-1.13	1.02	Δm_{t-5}^{k}	-0.02	0.05
Δi_{t}^{k}	0.32	2.66	Δm_{t-6}^{k}	0.10	0.04
			Δr_{t}^{k}	-2.24	1.78
			Δi_{t}^{k}	9.72	4.50
Adj. R^2	0.86			0.73	
F-Value	140.20			50.07	
Deg. Fr.	189.00			186.00	
BG	0.00			0.92	
RESET	0.00			0.00	
J.B.	0.77			0.31	

Table A 14 Regression Results for China from Thailand NARDL 1006 All Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	9.19	3.09	Intercept	27.90	5.76
m_{t-1}^{k}	-0.15	0.02	m_{t-1}^{k}	-0.50	0.04
r_{t-1}^{k+}	0.11	0.26	r_{t-1}^{k+}	0.09	0.51
r_{t-1}^{k-}	-0.77	0.43	r_{t-1}^{k-}	-2.52	0.80
i_{t-1}^{k}	-0.67	0.30	i_{t-1}^{k}	-1.95	0.57
Δm_{t-1}^{k}	0.92	0.05	Δm_{t-1}^{k}	0.40	0.05
Δm_{t-2}^{k}	-0.72	0.06	Δm_{t-2}^{k}	-0.12	0.06
Δm_{t-3}^{k}	0.48	0.06	Δm_{t-3}^{k}	0.14	0.05
Δm_{t-4}^{k}	-0.14	0.03	Δm_{t-4}^{k}	0.10	0.05
Δr_{t}^{k+}	-4.68	2.15	Δm_{t-5}^{k}	-0.02	0.05
Δr_{t}^{k-}	0.95	2.04	Δm_{t-6}^{k}	0.10	0.04
Δi_{t}^{k}	0.36	2.71	Δr_{t}^{k+}	-5.90	3.28
			Δr_{t}^{k-}	-1.84	3.04
			Δi_{t}^{k}	10.64	4.45
Adj. R^2	0.87			0.75	
F-Value	119.80			46.93	
Deg. Fr.	187.00			184.00	
BG	0.00			0.43	
RESET	0.00			0.00	
J.B.	0.70			0.28	

Table A 15 Regression Results for China from Thailand ARDL 100630 Milled Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	6.98	2.73	Intercept	3.36	3.07
m_{t-1}^{k}	-0.45	0.04	m_{t-1}^{k}	-0.46	0.04
r_{t-1}^{k}	-0.08	0.58	r_{t-1}^{k}	0.90	0.69
i_{t-1}^{k}	0.13	0.16	i_{t-1}^{k}	0.35	0.18
Δm_{t-1}^{k}	0.44	0.05	Δm_{t-1}^{k}	0.43	0.05
Δm_{t-2}^{k}	-0.12	0.05	Δm_{t-2}^{k}	-0.11	0.06
Δm_{t-3}^{k}	0.10	0.05	Δm_{t-3}^{k}	0.11	0.06
Δm_{t-4}^{k}	0.14	0.04	Δm_{t-4}^{k}	0.12	0.04
Δr_{t}^{k}	-1.34	1.94	Δr_{t}^{k}	4.09	4.14
Δi_{t}^{k}	6.19	4.77	Δr_{t-1}^{k}	-3.82	4.19
			Δr_{t-2}^{k}	1.49	4.19
			Δr_{t-3}^{k}	2.49	3.98
			Δr_{t-4}^{k}	-3.65	2.30
			Δi_{t}^{k}	2.78	8.73
			Δi_{t-1}^{k}	6.62	8.88
			Δi_{t-2}^{k}	-0.64	8.71
			Δi_{t-3}^{k}	-10.91	8.46
			Δi_{t-4}^{k}	5.31	5.28
Adj. R^2	0.73			0.73	
F-Value	60.82			32.88	
Deg. Fr.	190.00			182.00	
BG	0.12			0.45	
RESET	0.00			0.00	
J.B.	0.34			0.21	

Table A 16 Regression Results for China from Thailand NARDL 100630 Milled Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	24.90	6.28	Intercept	26.34	6.30
m_{t-1}^{k}	-0.48	0.04	m_{t-1}^{k}	-0.51	0.04
r_{t-1}^{k+}	-0.04	0.57	r_{t-1}^{k+}	-0.03	0.57
r_{t-1}^{k-}	-2.13	0.89	r_{t-1}^{k-}	-2.25	0.89
i_{t-1}^{k}	-1.68	0.63	i_{t-1}^{k}	-1.77	0.63
Δm_{t-1}^{k}	0.43	0.05	Δm_{t-1}^{k}	0.40	0.05
Δm_{t-2}^{k}	-0.10	0.05	Δm_{t-2}^{k}	-0.08	0.06
Δm_{t-3}^{k}	0.10	0.05	Δm_{t-3}^{k}	0.12	0.05
Δm_{t-4}^{k}	0.13	0.04	Δm_{t-4}^{k}	0.08	0.05
Δr_{t}^{k+}	-4.70	3.62	Δm_{t-5}^{k}	0.07	0.04
Δr_{t}^{k-}	-0.44	3.40	Δr_{t}^{k+}	-4.39	3.62
Δi_{t}^{k}	6.07	4.79	Δr_{t}^{k-}	-0.70	3.38
			Δi_{t}^{k}	8.80	4.90
Adj. R^2	0.74			0.75	
F-Value	52.46			49.34	
Deg. Fr.	188.00			186.00	
BG	0.24			0.17	
RESET	0.00			0.00	
J.B.	0.35			0.29	

Table A 17 Regression Results for China from Thailand ARDL 100640 Broken Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	-1.78	1.25	Intercept	-1.85	1.24
m_{t-1}^{k}	-0.06	0.02	m_{t-1}^{k}	-0.06	0.02
r_{t-1}^{k}	0.21	0.26	r_{t-1}^{k}	0.19	0.26
i_{t-1}^{k}	0.22	0.09	i_{t-1}^{k}	0.24	0.09
Δm_{t-1}^{k}	0.87	0.05	Δm_{t-1}^{k}	0.92	0.05
Δm_{t-2}^{k}	-0.59	0.06	Δm_{t-2}^{k}	-0.68	0.07
Δm_{t-3}^{k}	0.33	0.06	Δm_{t-3}^{k}	0.46	0.08
Δm_{t-4}^{k}	-0.09	0.04	Δm_{t-4}^{k}	-0.26	0.08
Δr_{t}^{k}	-0.54	1.03	Δm_{t-5}^{k}	0.15	0.07
Δi_{t}^{k}	-0.39	2.59	Δm_{t-6}^{k}	-0.05	0.04
			Δr_{t}^{k}	-0.82	1.01
			Δi_{t}^{k}	0.59	2.58
Adj. R^2	0.80			0.80	
F-Value	87.90			72.20	
Deg. Fr.	189.00			185.00	
BG	0.00			0.00	
RESET	0.32			0.68	
J.B.	0.00			0.00	

Table A 18 Regression Results for China from Thailand NARDL 100640 Broken Rice

Model 1			Model 2		
	Estimate	Standard Error		Estimate	Standard Error
Intercept	0.61	2.69	Intercept	1.25	2.64
m_{t-1}^{k}	-0.06	0.02	m_{t-1}^{k}	-0.07	0.02
r_{t-1}^{k+}	0.22	0.27	r_{t-1}^{k+}	0.22	0.27
r_{t-1}^{k-}	-0.02	0.40	r_{t-1}^{k-}	-0.12	0.40
i_{t-1}^{k}	0.02	0.28	i_{t-1}^{k}	-0.04	0.27
Δm_{t-1}^{k}	0.87	0.05	Δm_{t-1}^{k}	0.92	0.05
Δm_{t-2}^{k}	-0.59	0.06	Δm_{t-2}^{k}	-0.68	0.07
Δm_{t-3}^{k}	0.33	0.06	Δm_{t-3}^{k}	0.46	0.08
Δm_{t-4}^{k}	-0.09	0.04	Δm_{t-4}^{k}	-0.26	0.08
Δr_{t}^{k+}	-0.58	2.03	Δm_{t-5}^{k}	0.15	0.07
Δr_{t}^{k-}	-0.79	2.04	Δm_{t-6}^{k}	-0.05	0.04
Δi_{t}^{k}	-0.07	2.68	Δr_{t}^{k+}	-0.65	1.99
			Δr_{t}^{k-}	-1.44	2.00
			Δi_{t}^{k}	1.18	2.67
Adj. R^2	0.80			0.80	
F-Value	71.50			60.90	
Deg. Fr.	187.00			183.00	
BG	0.00			0.00	
RESET	0.22			0.57	
J.B.	0.00			0.00	